NSF SITE PANEL REPORT CONCERNING a DEEP, UNDERGROUND SCIENCE and ENGINEERING LABORATORY (5/28/03)

This report concerns three potential sites for a deep, underground science and engineering laboratory (DUSEL). These sites are the Homestake Mine in Lead, SD, a San Jacinto Mountain site near Palm Springs, CA, and the Soudan Mine near Tower, MN. Generic criteria for evaluation of each of the three sites were partitioned into two broad categories: (1) geological suitability and (2) relative costs. Geological suitability pertains to DUSEL requirements for development of access to and excavation of large deep, long-life underground cavities (~50 m linear dimension, ~2500 m deep, ~50 yr). Relative costs pertain to expense of developing access, cavity excavation expense and infrastructure. Application of these criteria and panel results are discussed for each site. Special concerns particular to a given site and concerns common to all sites are addressed in a separate issues section of this report. The panel was composed of seven recognized experts in mining, construction and permitting projects similar to those in the DUSEL proposals. Proposals were made available for review in advance of a panel meeting that was held the latter part of May 2003. Panel consensus and conclusions are presented at the end of this report.

HOMESTAKE MINE, LEAD, SD

The Homestake Mine at Lead, South Dakota, has been proposed as a site for a national underground laboratory to conduct a number of physics and earth science studies. The Homestake Mine operated as a gold mine from the 1880's until it was shut down in 2000. The mine is serviced by two shafts, one from surface down to the 4850 Level (4850 ft or 1480 m below surface), and another underground winze shaft that extends to the 8000 Level (2440 m). An extensive system of horizontal openings is present at about 46 m (150 ft) intervals in depth. There are more than 500 km (300 miles) of underground workings at the mine. The Davis neutrino experiment was in operation at a site on the 4850 Level for more than 30 years, up until the time of mine closure.

An upper campus for experiments is proposed at a site near the 3200 Level, and a lower campus for experiments is proposed at the 7400 Level. All access and service facilities at the mine have been maintained since the mine closed. Hence, development work to construct a site for any experiment would be minimal.

Geological Suitability

Geological mapping of each level, including cross-sections, was carried out; hence, the lithology and geologic structure of the mine are very well known. All the geologic data have been preserved, and in fact, are available in digital form in Vulcan – a mine visualization software package. Overall the rocks at Homestake are very hard and competent, so mine access openings have remained stable since they were driven. In addition, very large mine openings have been constructed at depth, including a chamber,

related to the mine air conditioning system, about the same size as the large chambers that will be required for some of the physics experiments. In situ stress measurements have been carried out at a number of locations; hence, the regional in situ stress is known. The wealth of geological data and extensive mining experience with ground conditions at depth show that there would be minimal uncertainty associated with construction and stability of the chambers required for physics experiments. In addition, there are a number of rock units and geologic structures that are very suitable for the earth science experiments. The availability of relatively easy access to a large, deep underground region for geo-science and geo-engineering experiment is also a very attractive feature of this site.

Relative Costs

Cost estimates have been broken down for access, cavities and infrastructure.

The existing shaft and underground access openings at Homestake will result in very low development cost for underground construction. In addition, the uncertainties involved in the cost of underground construction at the mine will be very low, in the 15% range. Cost advantages of this site also include existing ventilation, power and pumping systems.

Cavity construction costs at all proposed sites for the deep, underground science laboratory may be roughly the same once access is achieved. However, at Homestake there are important advantages for the lower campus in that similar sized openings at these depths (2400 m, 8000 ft) have already been constructed and remain stable. Thus, uncertainty in the cost of cavity construction will also be low, in the 20% to 25% range.

The existing infrastructure at the Homestake Mine is extensive. Power, water, pumping, ventilation and air conditioning, and secondary escapeways are all in place. These features will result in greatly reduced costs in constructing and maintaining the underground science laboratory at this mine. Existing infrastructure would allow simultaneous development of several experiments and related activities. Relatively low geological and cost uncertainties combined with existing infrastructure are feature that make the Homestake Mine a leading candidate for a DUSEL.

SOUDAN MINE, SOUDAN, MN

The Soudan proposal is based upon facilities and physics experiments that already exist at the Soudan, University of Minnesota site. The University of Minnesota is proposing to reuse the existing facilities on the 710 meter level (depth below surface, about 2330 ft) and to build a clean room. The site is located in St. Louis County, Minnesota, about 150 km (90 miles) north of Duluth, Minnesota. The current laboratory is located adjacent to the Number 8 shaft of the former Soudan Mine. The State of Minnesota owns the former mine and 1200 acres of surrounding property. The mine was closed some forty years ago. The Number 8 shaft is a three compartment rectangular concrete opening inclined at

78 degrees to the horizontal. Two of the compartments are used for hoisting; the current capacity is only 6 tons. The maximum size is 1.3 meters by 2 meters by 10 meters in height (4.3x6.5x32.8 ft). The current Number 8 shaft is inadequate for the requirements of the DUSEL. The University of Minnesota is proposing to develop a circular 5-meter (16.4 ft) diameter shaft from surface to a depth of 1450 m (4760 ft) and a second shaft from the 1450-meter level to the 2500-meter level (8200 ft). In addition, the University is proposing an 8-degree decline with a 5 m by 4 m (16.4x13.1 ft) cross-section plus a 5 m (16.4 ft) diameter raise for ventilation. The University is also proposing buying adjacent land from the present landowner to make room for surface facilities.

Geological Suitability

Northeastern Minnesota lies in the Canadian Shield. This region is geologically stable; rocks are on the order of one billion years old. The Soudan site itself is in the Vermilion Range, the northernmost of the three iron ore ranges in Minnesota. The lenses of iron ore are generally embedded in jasper, a hard, iron-bearing rock, which is in turn surrounded by a softer metamorphic rock known locally as greenstone (altered basalt). The current Soudan laboratories, and the proposed new facilities, are located in the greenstone regions. At this time the vertical extent and configuration of the greenstone and jasper formations are not known. However, since the site is in an old, stable shield area, there is every reason to believe that the underlying formations are also stable and competent. Determining the precise geology at depth is one of the tasks to be accomplished as part of the development of the laboratory.

A major issue in developing the Soudan site is access. In the first place, all the access systems for the deep laboratories will have to be built from scratch. This will become a major cost item and will have an impact on the early schedule of laboratory operation. The current proposal is to construct two circular access shafts and a set of ramps spiraling down to the deep laboratory. These will have average inclinations of 1 vertical to 7 horizontal, which is a grade of 14% or 8 degrees. Such relatively steep slopes would make access difficult at best.

The principal advantage of this site from a geological point of view is that it probably lies in stable formations of great competence, and therefore the construction of the large underground openings is feasible. The first major limitation is that the geology at depth is not known and will have to be established before major construction work proceeds. The second limitation is that the such steep access ramps that will difficult to travel by some vehicles.

Relative Cost

Comparison of relative costs involves three components: access, cavities, and infrastructure. The cost of access for the Soudan facility is expected to lie between those for Homestake and San Jacinto. The design includes two access shafts and a long and steep set of access ramps. The cost of constructing these shafts and ramps is difficult to

estimate, so a contingency of at least 50% must be incorporated in the cost estimate. Since the geology at the depth of the cavities is not known, the estimated cost of constructing the cavities must include significant uncertainty. It is expected that the rock will be competent, but a 50% contingency must be added to any cost estimate. The usable portion of the existing infrastructure at Soudan is expected to comprise about 10% of the needed infrastructure for the eventual facility. Thus, about 90% of the necessary infrastructure will have to be built anew at relatively high cost.

MT. SAN JACINTO, CA

This proposed site is in a desert environment near Palm Springs in southern California, a popular winter-season resort. The site is a "green fields" site with no prior development other than the existing Palm Springs Aerial Tramway. Mt. San Jacinto is a topographic high approximately 2,500 m (7620 ft) above the surrounding valley floors. Mt. San Jacinto is an igneous intrusive pluton composed of granodiorite, diorite and coarse-grained pegmatite dikes that are intruded into older metamorphic rocks (argillites, schists, gneisses). The proposal envisions accessing a deep underground chamber complex by one or two tunnels or, more properly, adits, starting at portals on the mountain flanks at an elevation of about 790 m (2520 ft), driving under the mountain to a depth below the peak (elevation 3293 m, 10 800 ft) of approximately 2,500 m (8200 ft) to provide shielding from cosmic ray phenomenon. The site is within the influence of the San Jacinto Fault (19 km or 11 miles southwest) and San Andreas Fault (10 km or 6 miles northeast) systems; both are considered active. Surface access and activities on Mt. San Jacinto are extremely limited because of restrictions imposed by existing state or federal park, wilderness, game preserve, or monument land use classifications.

Geological Suitability

Concern was expressed about the likely highly fractured and broken rock materials in the vicinity of the site due to igneous intrusions and structural movement over time from historic seismic and other activities of deformation that could result in tunnel and laboratory space excavation and stability problems.

Provisions in place by federal and state park authorities for wilderness, game preserve and monument protection will severely restrict if not prohibit surface access needed for geophysical and exploration drilling equipment. Thus, data acquisition necessary to obtaining rock mechanics, fracture, fault and groundwater information essential for planning and design of the proposed tunneling and laboratory space design would be difficult if not impossible. Deep tunneling experience shows that projection of surface data to depth is a highly uncertain and risky with respect to safety, scheduling and costs. Advancing these facilities is not advisable without adequate data on rock mass characteristics including ground water and relationships to faulting, seismicity and so forth.

The proposal does not adequately address the important environmental issue of proper disposal of at least an estimated 160 000 cubic meters of waste rock. Storage at the surface near tourist facilities in the Palm Springs area would not be a favored option. Other methods of disposal would require additional costs of transport to another surface storage area or possibly the material could be used for construction, highway or other uses, if approval were obtained from regulatory agencies. The operation would likely be considered a mine should waste rock be sold; the facility would then fall under MSHA control during construction. Disposal by crushing for later sale as aggregate could also create issues with existing aggregate operations.

Information about groundwater characteristics in the immediate and general vicinity of the proposed site is unknown because of the obvious lack of exploration bore holes and monitoring well information in nearby valley alluvial sediments. Such information is critical to evaluation of site feasibility for excavation and project operation. Groundwater data are especially important because of the presence of extensive fracturing and major fault systems. Disturbing fracture flow systems, even during periods of low to zero flow, could also result in impacts to alluvial valley aquifer recharge and spring discharge systems, plus private well yield and water quality. Interception of fracture flow zones would require additional considerations for tunnel grouting, handling and disposal with possible treatment of dewatering flows, all of which would require special permitting.

Relative Costs

The proposal favors a least cost, single adit with a roadway and a pedestrian walkway, divided by a 0.6-m-wide reinforced concrete wall for fire protection. Public perception, and actual fire incidents in long tunnels in recent years, as well as the difficulties and hazards of ventilating through a single adit, and likely CalOSHA regulatory interpretations, make the feasibility of finalizing a single adit concept unlikely. A twin adit concept is more workable albeit more costly. A modern TBM could drive such adits with little difficulty. However, there is a great deal of uncertainty in forecasting in-situ rock mass conditions because of the lack of deep exploration and rock mass characterization data, and the suspected low rock mass quality caused by shearing, uplift, and compression of the Mt. San Jacinto igneous body during numerous episodes of faulting and uplift. Constructability of the adits is thus problematic and difficult to assess until such time as the adits are actually under construction. There are successful case histories of long tunnels being driven under deep cover with very little deep exploration, due to the speed of tunnel advance and the ability to respond to a wide variety of ground conditions as encountered; but the probability of success is estimated at only 10% to 15%. Because of the lack of data and attendant risk, adit (tunnel) cost estimates should bear a contingency of 300 %.

Design of science chambers to be excavated under 2,500 m (8200 ft) of cover is also highly uncertain because of the lack of deep exploration and rock mass characterization, and the suspected likely low-rock-mass quality of the Mt. San Jacinto igneous body. Chambers at 50-m spans and heights, while constructible, should have a contingency on cost estimates of at least 100%.

The site is a "green fields" site with little infrastructure in existence, other than what might exist for the Palm Springs Aerial Tramway, which the proposal does not discuss. Thus, an entire infrastructure will have to be developed to achieve construction and operations of the DUSEL facility. However, the proposal discusses environmental constraints that will be necessary to "hide" or "disguise" surface facilities. This presumably will include screening berms, plantings, rock and desert-soil colored structures and concrete, and other more costly construction techniques. Bringing sufficient power into the site may have to be accomplished by buried cables from the more distant power sources. Infrastructure costs for this site, like the costs for access and cavity excavation are therefore extremely high.

Panel review of the proposal for location of the proposed DUSEL project at the San Jacinto site indicated that one advantage to this location would be the potential to develop a facility at a site unaffected by past mining activities or laboratory operations. An opportunity to develop a project from scratch is appetizing from a purely scientific research and development viewpoint without impacts from past or existing operations. However, the general consensus was that such a luxury was not defensible because of several critical data gaps unlikely to be bridged, attendant schedule constraints and high relative cost.

OTHER ISSUES

Issues identified by the panel that are common to all sites include disposal of large volumes of waste rock from access development and detector cavity excavation and an associated awareness of the importance of a timely environmental impact statement (EIS) and associated permitting. An EIS often requires up to three years for completion at a cost of several million dollars. Usually no project activity is allowed in advance of the record of decision (ROD) that may require significant changes in the proposed operating plan for the site considered. In this regard, an important consideration is the relationship of any DUSEL to local and Native American interests.

Drilling to great depth is also an important consideration for geoscience and the study of extreme microbial life. Experience at the existing mine sites, Homestake and Soudan indicates no obstacles to deep hole drilling. However, uncertainty about geological conditions at San Jacinto pose some risk to this activity. San Jacinto also poses a seismic hazard not common to the other two sites.

An important issue specific to the Homestake site concerns pumping water. Currently the mine, which contains well over 500 km (300 miles) of accessways, pumps about 34 l/s (500 gpm). The question is whether stopping pumping and subsequently dewatering the flooded region of the site is desirable. The mine owner apparently desires to stop pumping now and to dewater later. In their view, this would involve a lower cost, than continuing to pump. However, the panel was unanimous in the opinion that continuing to pump is the most desirable option. Important reasons to continue pumping include

maintenance of mine stability, avoidance of equipment replacement or damage, consistency with existing operating approvals and preservation of the rock mass environment. The latter is especially important to the study of ancient microbial activity. In the panel's opinion any potential cost savings would not be worth the potential for destabilizing the flooded region and neutralizing this region with respect to microbial life study.

CONCLUSION

The panel concludes that Homestake is by far the most favorable site for a DUSEL. Existing access to depth and mining experience that clearly demonstrates feasibility of excavating large caverns at relatively low cost in addition to existing infrastructure made the Homestake Mine an obvious choice. Access via 500 km (300 miles) and more of tunnels at Homestake was especially favorable to geo-science and –engineering studies.

The San Jacinto site was considered to be the least favorable site and, in the opinion of the panel, not a viable DUSEL candidate. The high degree of uncertainty about geological conditions, the potential for protracted environmental and permitting processes at this undeveloped site and relatively high costs made Mt. San Jacinto the least favored site of the three.

The Soudan Mine was considered a possible "back-up" DUSEL site, but was not favored as a first choice by any of the panelists. Uncertainty about rock mass conditions at depth, the need to develop costly ramps and shafts for deep access and the implied necessity for doing geo-science and –engineering from boreholes made this site relatively unattractive.

There was very little variability amongst panel members in relative rankings of factors pertaining to each site.

DUSEL site panel
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